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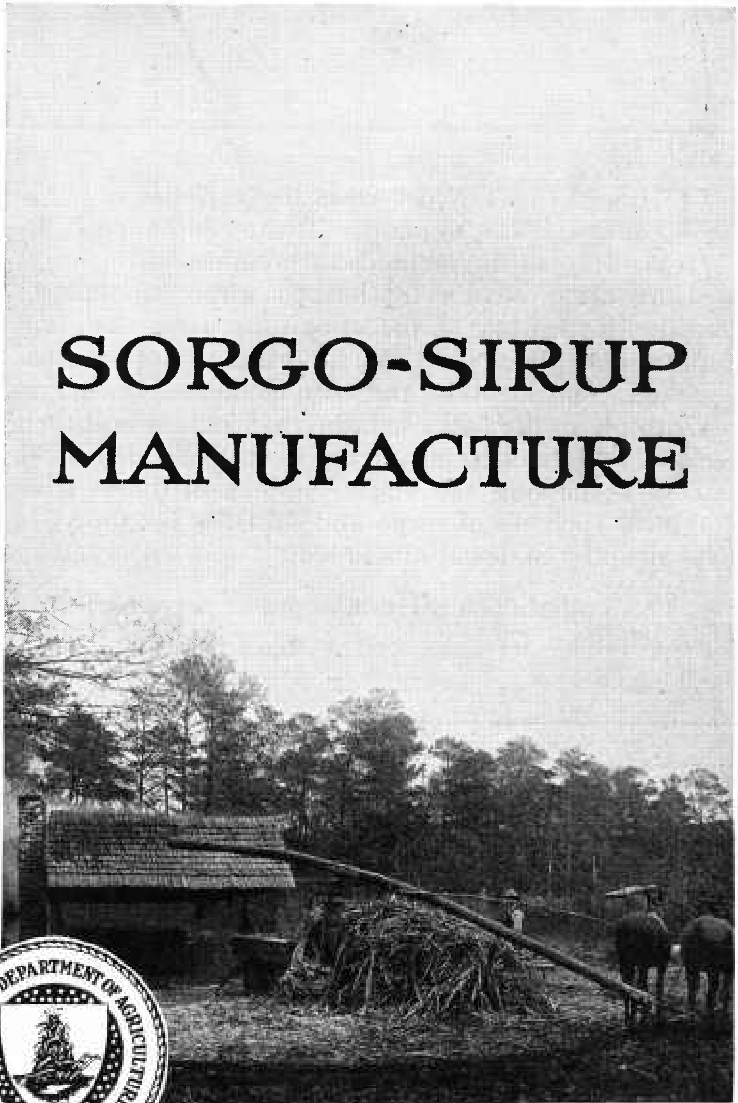
SORGO-SIRUP MANUFACTURE



THIS BULLETIN describes the varieties of sorgo and tells how to plant, cultivate, and harvest the crop. It gives the methods for manufacturing sorgo sirup, often incorrectly termed sorgo "molasses," with illustrations of the apparatus used. The approximate yields of stalks, of sirup, and of seed are given. The location and arrangement of a sorgo-sirup plant, the fuel used, the by-products and their uses, and making sirup on shares are discussed. Tables showing the sugar content of juice from typical varieties of sorgo and statistics for the yield of sirup by States are included.

This bulletin is a revision of and supersedes Farmers' Bulletin 477.

Washington, D. C. February, 1924

Farmers' Bulletin 1389, page 1, line 2,

"<u>larger</u> returns" should be "<u>large</u> returns."

SORGO-SIRUP MANUFACTURE.[1]

By A. HUGH BRYAN, *formerly Chief, Sugar Laboratory, Bureau of Chemistry*, and SIDNEY F. SHERWOOD, *Chemist, Office of Sugar Plant Investigations, Bureau of Plant Industry.*

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USE OF SORGO FOR SIRUP.

SORGO is more widely distributed than sugar cane or sugar beets, gives larger returns to the acre, is easy to cultivate, and contains enough sugars to afford big yields of sirup at a satisfactory profit. At one time it was believed that sorgo had great value in the production of sugar. In competition with sugar cane and sugar beets, however, none of the varieties of sorgo now known can be made to produce sugar profitably. Sorgo juice contains gummy materials, like starch, which interfere with filtration and retard crystallization of sugar, and also comparatively large quantities of sugars other than the ordinary sugar of commerce (sucrose) that retard, and sometimes prevent, crystallization. The yields of crystallized sugar obtainable in this way are too small to be profitable.

The manufacture of sorgo sirup, a comparatively simple process, does not call for expensive apparatus or machinery nor for dangerous chemicals. The greatest cleanliness and care, however, are necessary to produce sirup of a fine quality.

The term sorgo "molasses," often applied to sorgo sirup, does not properly describe the product and should not be used. It probably came into use because sorgo sirup often looks somewhat like molasses, in that it is dark and thick and flows slowly. Sirup like sorgo, cane, or maple sirup is made by evaporating directly either the raw or clarified plant juice, without removing any of the sugar. Molasses is the liquid which remains after part of the sugar has been removed, as in the manufacture of cane sugar. As no sugar is made from sorgo, the use of the term "molasses" in this connection is incorrect.

[1] Sorgo is called sorghum in many parts of the country. Until recently the sirup from sorgo was generally known as sorghum sirup.

VARIETIES OF SORGO.[2]

In the broad sense of the word, sorghum includes all the groups popularly known in this country as sorgo (sweet sorghum or saccharine sorghum), kafir, broomcorn, shallu, kaoliang, durra, and milo, but only the sorgos are of practical value for the production of sirup. Sorgos are recognized by their sweet sap or juice. As a rule, they are tall, with a leafy growth, branching only sparingly at the upper nodes or joints, and not stooling much at the base under ordinary cultivation. The seed head varies from the close compact "club" head of the Sumac variety through the more open heads of Orange and Gooseneck, to the loose and often widely spreading heads of the Amber and Honey varieties.

Fig. 1.—Head of Amber sorgo.

Many varieties are now under cultivation. Some produce fairly true to type, but others show a great variation in type in a single field planted with seed from one so-called variety. Moreover, a variety known under one name in one place may have another name in some other place. Ball has divided the sorgo varieties into three or four groups, each consisting of a single well-marked variety and a number of forms derived from it.

AMBER.

Amber is an early variety, requiring from 70 to 100 days to reach maturity, depending on the latitude, season, and soil. It has rather slender stalks and comparatively few and narrow leaves. The seed heads, usually black, vary in shape and size and are rather loose (fig. 1). One variety of this Early Amber, known as Folger, originated as an improved sirup variety, having the characteristics of Amber. Other varieties of some prominence are the Red Amber and the Minnesota Amber.

ORANGE.

The orange variety (fig. 2) has larger and heavier stalks, larger and more abundant leaves, and heavier and more compact seed heads

[2] The description of varieties is taken in part from Farmers' Bulletin 246, "Saccharine Sorghums for Forage," by Carleton R. Ball.

than the Amber variety. Just before ripening the seeds are almost white. The Early Orange, as this standard variety is usually called, requires about two or three weeks longer than the Amber to reach maturity. Because it grows higher and has larger stalks it gives a slightly heavier yield per acre. Various forms of this variety, including Kansas Orange and Late Orange, are offered on the market.

The Colman variety is used by many for sirup making. In size, character of the seed head, and time required for maturity it is practically the same as the Orange variety.

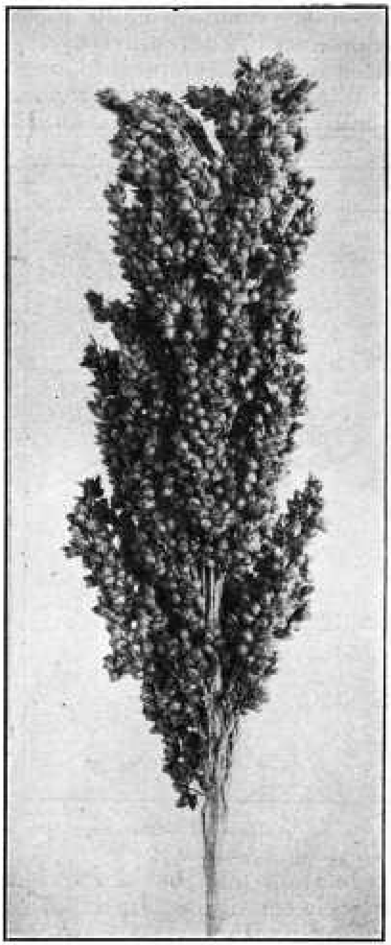

Fig. 2.—Head of Orange sorgo.

SUMAC OR RED-TOP.

Sumac, or Red-Top, is a stout, stocky variety with many large, broad leaves. The seed heads are stout, thick, cylindrical, and erect, and the reddish-brown seeds are the smallest of any (fig. 3). This variety grows from 7 to 10 feet high, is usually of a very even growth throughout a field, and matures in from 90 to 120 days. It is cultivated extensively in the South.

GOOSENECK.

Gooseneck is distinct from all of the other varieties grown in this country. Its name is probably derived from the recurved and pendent reddish stems (fig. 4). It grows commonly from 10 to 12 feet high, and when thinly sown, for sirup making, the stalks are from 1 to 2 inches in diameter at the butt. This variety was extensively grown in the South, especially Texas. Ripening much later than Amber and a week or 10 days later than Orange and Sumac, it can not be grown in the Northern States.

HONEY.

The stalks of the Honey variety are from 7 to 10 feet high, are stout, from 1 to 1½ inches in diameter at the base, and very sweet. The stems are markedly tender in comparison with those of other stout varieties. It ripens very late, however, requiring from 130 to 140 days to mature, and therefore is best adapted to the South.

SELECTION OF A VARIETY.

For northern regions, where the growing season is short, some form of Early Amber or of Early Orange, preferably the former, must be selected, while farther south all the varieties may be used. A variety grown one season may produce a good sirup, but under different climatic conditions another year it may not yield so good a product. The nature of the season seems to exert a marked influence on the composition of the plant.

When a variety has repeatedly given good yields and a good quality of sirup, the seed should be carefully selected for replanting. Typical fully-ripened seed heads should be carefully air dried, threshed, and cleaned.

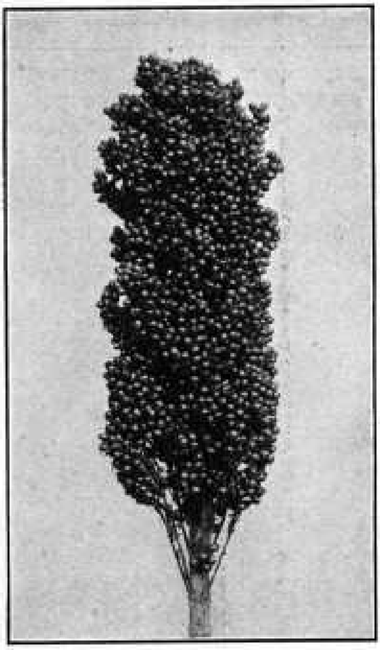

FIG. 3.—Head of Sumac sorgo.

CULTURE OF SORGO.[3]

Good seed of the right variety is necessary for the best yields, but other equally important factors, such as preparation of the soil, time and rate of seeding, and manner of planting, must not be neglected. Perhaps more failures to secure satisfactory crops are due to improper seeding than to any other cause.

PREPARING THE SEED BED.

Although a large part of the land planted to sorgo is left unplowed until a short time before seeding, this practice is by no means advisable. For the best yields there must be a firm seed bed, obtained by plowing the land early in the fall and harrowing or disking to keep down weeds until seeding time. Such preparation allows whatever vegetation may be in the soil to decay and leaves it in the best tillable condition. In the drier regions this treatment serves to take in and retain any moisture that may come during the winter season and to lessen the chance of failure from drought. In the same manner it increases the yield in more favorable seasons. In the more humid sections early preparation is preferable, although not so necessary as in the drier regions. The land is sometimes prepared by "bedding" or listing with a middle buster or a turning plow.

PLANTING.

The planting of sorgo deserves more careful attention than any other operation entering into the production of the crop. The time,

[3] This section was prepared originally by A. B. Connor, Bureau of Plant Industry.

method, and rate of seeding mean success or failure in the degree in which they have been properly or improperly done. It is therefore of vital importance that the farmer attend carefully to the planting of his crop.

Time of planting.—Sorgos are usually planted soon after corn. when the ground is thoroughly warm. They may be planted at any time after that date until as late as will permit the crop to ripen safely. In the Southern States the first of April is considered early planting. Northward, using the northern line of Louisiana as a base, the season grows later at the rate of about 1 week for every 150 miles. It is usually well to make two or three different plantings at intervals of about 10 days or 2 weeks, so that all of the crop will not mature at the same time.

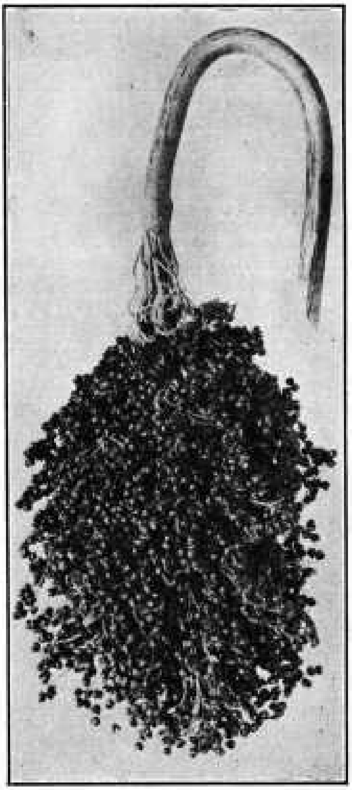

FIG. 4.—Head of Gooseneck sorgo.

Method of planting.—For sirup production, sorgo should always be planted in rows 3 or $3\frac{1}{2}$ feet apart. This may be done with a single or double row planter, either on a bed, on the surface, or in a lister furrow, depending on the section where the crop is grown. Furrow planting is most common in the drier regions, and it is practiced to some extent in the humid sections. In some of the lower and poorly drained lands planting is made on a bed, but only under such conditions should this method be used.

Rate of seeding.—The rate and regularity of seeding largely influence the yield of sirup, regardless of the method used. Seeding should be done so that the plants will be very evenly distributed and average a distance of 4 to 6 inches in the row, or even more in the drier regions. The quantity of seed required to plant an acre is small, varying from 2 to 8 pounds, depending upon the rate and method of planting.

CULTIVATION.

While sorgo will grow and give fair yields with little or no cultivation, this is by no means the most profitable method of producing the crop. Careful cultivation has repeatedly been known to increase materially the yield per acre. The first cultivation can be given with a spike-toothed harrow, and as soon as possible afterward it should be cultivated deeply. Later in the season at least two additional shallower cultivatings should be given for the best results. Sorgo can be cultivated to advantage until it begins to put out heads, provided care is taken not to destroy the surface feeding roots.

HARVESTING.

The stage at which the sugar content of sorgo is greatest has been the subject of much investigation. The figures in Table 1 are the result of about 2,740 analyses of sorgo made at different stages of growth.

TABLE 1.—*Sugar content of sorgo at different stages of growth.*[1]

Stage of cutting.	Sucrose.	Invert sugar.
	Per cent.	*Per cent.*
Panicles just appearing	3.51	4.50
Panicles entirely out	5.13	4.15
Flowers all out	7.38	3.86
Seed:		
In milk stage	8.95	3.19
Doughy, becoming dry	10.66	2.35
Dry, easily split	11.40	2.03
Hard	13.72	1.56

[1] Peter Collier, "Sorghum: Its Culture and Manufacture" (1884), p. 198.

From the time the seed is in the late milk stage until it is becoming dry the cane is in the best condition for sirup making. Some prefer to wait until the seed is hard before cutting, as the sugar content is still higher then, but they run the danger of a frost before all of the cane is worked up.

Cutting may be done by hand or with a harvester. As a rule, before cutting, the leaves are struck off with a wooden paddle or raked off with a two-pronged iron tool. Sometimes, however, they are not removed until after cutting. When harvested by hand, the individual stalks are cut about 6 or 8 inches above ground and laid across the rows with all the heads in the same direction. With a harvester and binder, the cutting and binding in bundles form one operation, and all the seed heads are at one end of the bundle.

Some makers leave the cut stalks in the field for a day or two to wilt the leaves, which is said to improve the quality of the sirup. The seed heads are removed and left in the field to be collected after the harvest. For a good grade of sorgo sirup all leaves and seed heads must be removed from the cane, as these, on passing through the mill, may give a bad flavor to the juice and resulting sirup, introduce dirt and plant material into the juice, and retard clarification. Moreover, leaves which have become dry have a tendency to absorb juice as it is pressed from the stalks, thus decreasing the yield of juice and sirup. In removing the seed heads, about 6 to 18 inches of the upper cane should be cut off, as this part contains little sugar and many impurities. Suckers also should be discarded for the same reason.

The harvesting should progress with the mill work, no more than can be worked in two days being cut at one time. When the weather is cold the stalks may be cut and shocked. A freeze does not hurt the crop, provided it can be worked up just as soon as it thaws. On freezing, the cells of the stalks are broken, and, on thawing, decomposition quickly sets in. A frost will not hurt ripe sorgo materially, but it will spoil immature sorgo. Frosted sorgo, like frozen sorgo, should be worked up as soon as possible. In Louisiana sugar

cane is "windrowed" when a frost or freeze is expected—that is, the cane is cut and laid on the ground between the rows, the leaves serving as a protection. In the case of sorgo, under such conditions, if the weather is warm during the middle of the day, the leaves on the stalk soon produce a "heating" of the pile and decomposition sets in. Heated sorgo and frosted sorgo affect the flavor of the sirup. One maker states that by shocking the stalks with leaves and heads on he has kept sorgo in good condition for many weeks. This, of course, was during cool weather, for even when standing in shocks it may "heat."

For sirup making the best stage for cutting is just before hardening of the seed. Earlier than this the crop is too green and the resulting sirup will have an unripe taste. If cut when the seeds are very hard, the juice may be difficult to clarify, and the flavor of the sirup is not good.

Sorgo may yield as much as 15 tons or as little as 4 tons an acre. The average crop is 8 to 10 tons. With a 3-roller mill, a ton of cane should produce from 700 to 1,200 pounds of juice, giving from 8 to 30 gallons of finished sirup, depending upon the richness of the juice. Taking 10 tons as the average yield, from 60 to 300 gallons of sirup to the acre may be obtained. The yield of sirup per acre commonly obtained varies from 75 to about 200 gallons. It depends upon the kind of mill, the care used in the milling and manufacturing processes, and, more particularly, upon the variety of sorgo and the attention given to seeding and cultivating. A satisfactory stand and proper cultivation usually increase the number of gallons to the acre. A higher yield per ton is usually secured at large plants where the juice is extracted by passing the stalks through a series of 3-roller mills and where the evaporators make for efficiency. At these mills a larger proportion of juice is extracted and less loss occurs during evaporation and skimming than in smaller plants. At one large mill the yield of sirup varied from 180 to 220, with an average of 200, gallons per acre.

MANUFACTURE OF SORGO SIRUP.

This discussion is designed for the benefit of small makers of sirup rather than for those having large, well-equipped plants.

EXTRACTING THE JUICE.

The ordinary method of obtaining juice from sorgo is by milling—that is, running the stalks between iron rollers set a certain distance apart.

The primitive mills were made by placing two logs upright, side by side, in a heavy frame. To one of the logs, extending above the frame, was attached a large sweep. On turning this and feeding the stalks between the rollers, the juice was squeezed out. This method was very wasteful, as not more than 25 to 30 per cent of the juice was extracted.

It is doubtful whether this kind of mill is used at the present time. The wooden rollers have been replaced by iron rolls, and today many makes of 2-roller mills are on the market. The extraction with these is better than that with the wooden rollers, but is not equal

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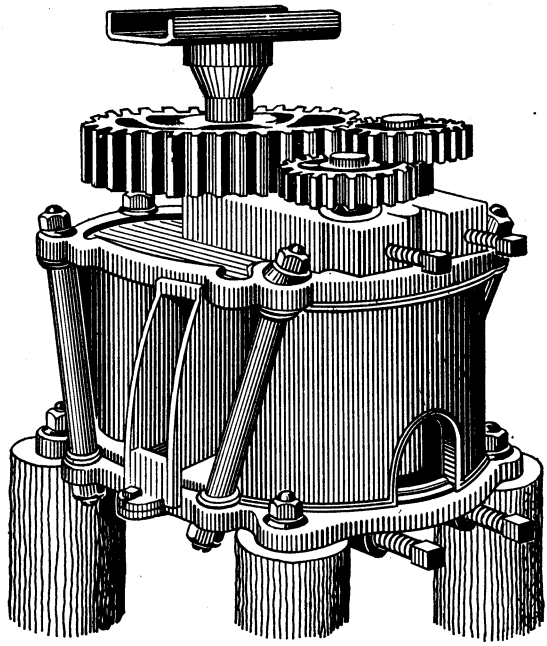

FIG. 5.—Heavy 3-roller vertical horsepower mill.

to that with the 3-roller mill. Three-roller mills may be obtained with upright or horizontal rolls. The smaller mills (figs. 5, 6) are operated by horses or mules, the larger ones (fig. 7) by power. It is easier to feed mills with grooved rolls, and the stalks tend less to twist to one side in such mills.

A good mill should be easily taken apart and new pieces substituted when breaks occur. It must run smoothly and true for good results. The rolls must be capable of adjustment to any distance from one another. In setting up such mills, care should be taken to have the mill level and rigid on the frame or upright supports, which should be carefully braced. Without these precautions, imperfect pressing will result and a break in the mill may be caused. Power mills (fig. 7) are either single or double geared, so that they can be connected directly with some form of farm engine. Some power mills are driven by traction engines. Power mills are better than horsepower mills, as the crop can be worked up more easily and quickly. A feed table (fig. 8) is an important addition to a milling outfit, especially for a power mill, as it allows the stalks to be arranged in some order before

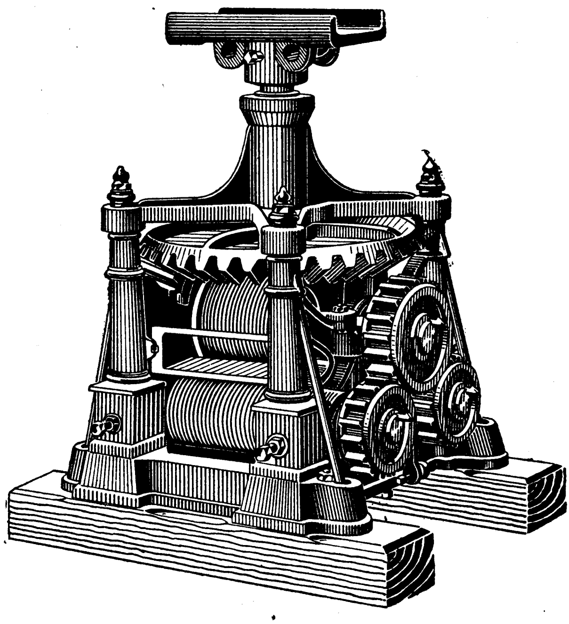

FIG. 6.—Three-roller horizontal horsepower mill.

entering the rolls, thereby securing a more even feed. A bagasse carrier, geared to the rolls (fig. 8), delivers the bagasse (crushed stalks coming from the mill) some distance from the mill.

In making sorgo sirup on a large scale, two or more 3-roller mills may be used, one following the other. In this case the bagasse as it comes from the first 3-roller mill is often moistened slightly with water and then passed immediately into the second mill. This method increases the extraction.

Sorgo ordinarily contains from 70 to 80 per cent of water and about 10 to 12 per cent of fiber, but it is impossible to obtain all of

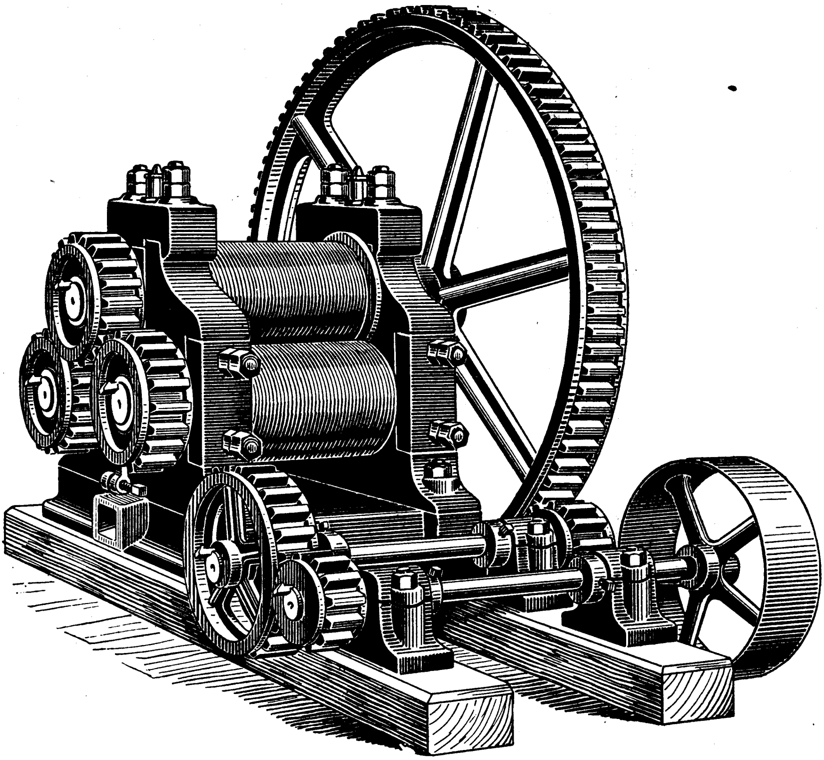

FIG. 7.—Three-roller power mill.

the water as juice. With a 3-roller mill, at least 50 per cent of the weight of the stalks should be obtained as juice unless they are very hard and dry. With a good mill and close setting, 60 per cent is not too much to expect. The "feed," or quantity of stalks in the mill at one time, should be light or heavy according to the adjustment of the rolls. When they are set "open," or apart, the feed should be heavy; when they are set close together the feed should be light. In all cases it should be regular and uniform. It is evident that when the rolls are set "open" juice is wasted when the feed is light; with a close-set roll there is also a loss of juice when the feed is irregular and uneven over the roll.

Juice obtained by moderate pressing is purer than that obtained by extreme pressure, by which more impurities from the rind and joints of the stalks are extracted. Sirup made by moderate pressing usually has a better flavor than that made by heavy pressing. Where sorgo is cheap and abundant it is inadvisable to increase the extraction of the juice greatly by excessive pressure.

SETTLING THE JUICE.

The raw juice coming from the mills should pass into collection or storage tanks. These may be merely rough barrels or they may be metal or concrete tanks. Before entering these the raw juice should pass through a fine sieve or screen to remove particles of cane, dirt, etc.

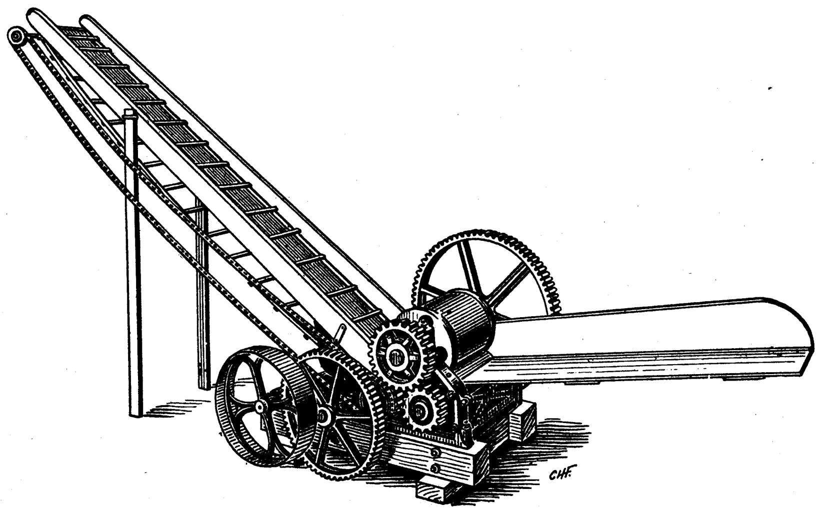

FIG. 8.—Mill with feed table and bagasse carrier.

Raw sorgo juice contains suspended material which slowly settles to the bottom. If it remains in the juice, it collects in the evaporator at the point of entrance of the juice, where it may burn. It is advisable, therefore, to remove as much of it as possible before evaporation is begun. Heating the juice tends to hasten settling. The addition of clays, sometimes suggested as an aid to settling, is not recommended. Two or more settling tanks should be used in order to give the juice in one enough time to settle and be drawn off while another is being filled. The juice should never stand for as long a period as overnight.

Settling tanks should have some arrangement for drawing off the clear juice without disturbing the settlings, or for drawing off first the settlings and then the clear juice. A swinging barrel (fig. 9) can be used by manufacturers working on a very small scale. Connections suitable for tanks are shown in Figure 10. By carefully opening the cock (*A*) near the bottom, the cloudy liquid is allowed

to flow out into a small vessel and is turned into its proper tank when it begins to run clear. By pushing down the sliding overflow pipe (*B*), which passes through the bottom of the settling tank, so that its upper end is below the surface of the liquid, the clear juice is drawn from the surface down to the settlings. An outside swing pipe (*C*) draws the settlings from the bottom of the first tank; then the clear juice follows. When the long arm is turned down the liquid flows out; when it is turned up, the flow stops.

Possibly the best form for tanks (*D*) has a swing pipe inside the tank. By keeping the upper end of the long arm just below the surface of the liquid the sediment is left behind. A float may be connected with the long arm, keeping it just below the surface of the liquid and arranged so as not to draw the settlings. When standing erect the arm must be long enough to reach above the surface of the liquid in the settling tank, and the swing pipe should be placed close to the bottom of the tank, far enough from the side to allow the long arm, when turned down entirely, to lie flat upon the bottom, in order to draw all the liquid as well as the sediment from the tank. The long arm of the nipple should fit the threads tight enough to hold the weight of the pipe in any position and not allow it to drop down under any condition. The settlings, or sludge, can be used for feeding hogs. When the settling has been done hastily, the sludge should be drawn off to another tank and allowed to settle more slowly, thereby saving more of the juice.

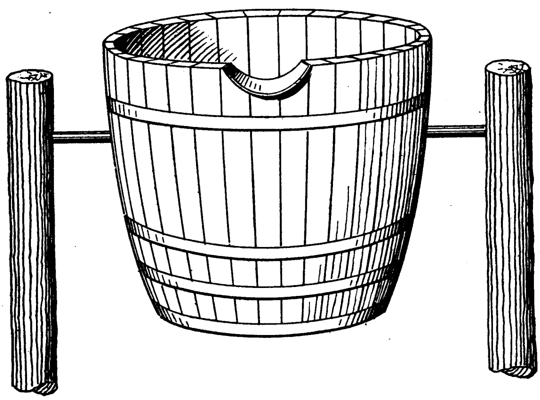

FIG. 9.—Swinging barrel for pouring off settled juice.

CLARIFYING THE JUICE.

The purpose of clarification is to remove objectionable substances from the raw juice, so that a better grade of sirup may be obtained. The impurities in sorgo juice vary, depending on the season, variety of sorgo, pressure used in extraction, and the ripeness or condition of the stalks. Undissolved impurities are removed to a great extent by settling, but those present in solution must be removed by heat or by chemical treatment. The addition of chemicals, however, while tending to throw out certain impurities, generally leaves in their place part of the foreign substance added and very often completely changes the flavor of the resulting sirup. Many schemes and many substances have been proposed for clarification. Some do the work, while the use of others is questionable.

As a general thing, the small producer of sirup should not attempt to employ chemical methods of clarification. Great care must be

used in adding chemicals for this purpose, as a slight excess of some substances used for this purpose may ruin the color and flavor of the sirup. Allowing the juice to come in contact with iron surfaces should be avoided as far as possible, for iron tends to darken the sirup.

HEAT.

When the raw juice is heated albuminous matter is coagulated and rises to the surface. This can be skimmed or brushed off. In coagulating, this material tends to remove some, and generally most, of the suspended matter. Some makers provide special pans or tanks for this heating or clarification. The temperature of the juice is brought nearly to the boiling point, the heat is turned off,

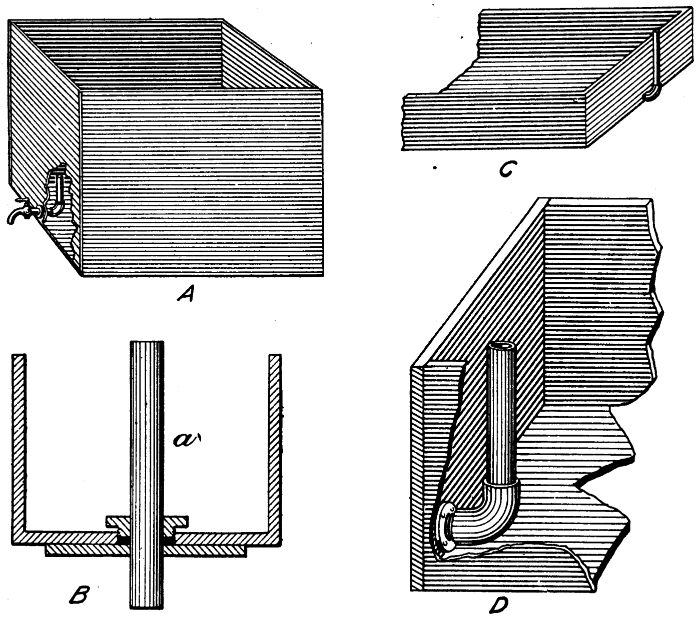

FIG. 10.—Tank connections for drawing off juice: *A*, settling tank from which the clear liquid is drawn by an upright nipple near the bottom; *B*, sliding overflow pipe for decanting liquids; *C*, outside swing pipe for drawing liquid from the bottom; *D*, inside swing pipe for decanting liquids from near the surface.

and the juice is allowed to stand. The clear layer is drawn off for evaporation. This process is to be preferred in manufacturing on a small scale.

HEAT AND LIME.

At certain seasons, and with certain varieties of sorgo, the raw juice may be high in acid. Lime is sometimes added to partially neutralize this acid. This also precipitates some of the organic matter. It is a question, however, in using lime how much more of the organic impurities are removed from the raw juice than by heat alone. The procedure when lime is used is as follows:

Slake completely a quantity of lime with water and then add more water to produce a thin whitewash. Strain the whole through a

mesh screen, one-eighth inch or even finer, to remove lumps, unburnt stone, etc. If still too thick, dilute with water. Add only enough of this solution to almost neutralize the acidity, this point to be determined by testing the juice before and after adding the lime (the whole being stirred thoroughly) by the following method: Dip a piece of blue and a piece of red litmus paper in the solution. If it is acid, the blue litmus paper will turn red and the red litmus paper will remain unchanged; if the solution is alkaline, the blue litmus paper remains unchanged in color while the red litmus paper turns blue. If neither one is affected, the solution is neutral.

It is far better to lime lightly at first, noticing the color of the juice after the addition of lime, the tint of the blue litmus paper after wetting it in the thoroughly stirred limed juice, and the quality of the sirup produced. Then add lime to the next lot of juice, keeping always on the safe side—that is, the acid side. Liming should cease when the juice gives only a faint red to litmus. If it does not change the color at all, too much lime has been used, and fresh unlimed juice should be added.

Litmus paper can be obtained in "books" or in sheets. Books are a little more expensive but easier to use. If sheet litmus is used, a piece should be cut for immediate use, clipped into small pieces, and put into a small bottle, which may be corked and carried in the pocket. The rest of the sheet should be put away in a corked bottle for future use. Acid vapors in the air and fingers moist with acid juices redden and spoil blue litmus. By moistening the tip of the finger and touching one of the pieces of the blue paper it may be picked up without handling the others. In using lime for clarification, the greatest care must be taken not to make the juice alkaline by the addition of an excess, which would spoil the flavor and color of the sirup.

MISCELLANEOUS METHODS.

Phosphoric acid compounds.—In this treatment two methods have been used. In one, the phosphoric acid is added to the raw juice and then limed before heating. In the other, lime is added to alkalinity, then phosphoric acid is added to a slight acidity, and the juice is heated. This procedure greatly changes the flavor of the resulting sirup, and its use is very questionable.

Lime carbonate (whiting).—Ordinary slaked lime is strongly caustic, but whiting, or carbonate of lime, is not. When using this material, heat the juice and stir it vigorously while the whiting is being added, controlling the quantity by means of litmus paper. Much more whiting than lime is required to neutralize the juice. The greatest care must be taken to leave the juice slightly acid. If too much whiting has been used, the proper acid reaction may usually be regained by adding fresh raw juice.

TEST GLASS.

As a means of watching the progress of clarification, a test glass may be used to withdraw and examine samples. Prepare a handle from a one-half to three-fourths inch board, about 2 feet long, and notch it (fig. 11). Place a 2 or 4 ounce wide-mouth glass bottle

in the notch, and fasten it into position with galvanized-iron wire. This is very convenient at various stages of sorgo-sirup manufacture.

FILTRATION.

Sorgo juice is extremely difficult to filter, especially after it has been heated, as some of the materials naturally present in it quickly clog the filters. This is true also of juice that has been heated and allowed to settle. Cold raw juice may be filtered if infusorial earth, or kieselguhr, a claylike filter-aid material, is added to it, but the results thus obtained are unsatisfactory. Slightly better results are obtained when the infusorial earth is added to juice that has been heated and limed, but the whole process requires very careful chemical control. In both cases pressure filters must be used. The small-scale producer should not attempt to filter the juice.

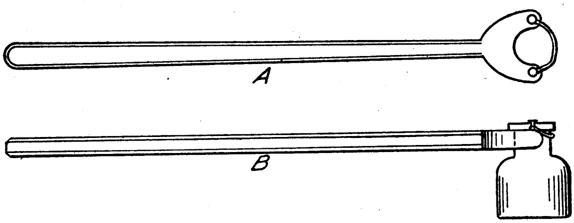

FIG. 11.—Test glass and handle.

EVAPORATION OR CONCENTRATION.

The object of the process of evaporation is to remove the water from the raw juice and thereby thicken it to a sirup. The methods ordinarily used in the small-scale production of sorgo sirup are as follows:

KETTLES.

The simplest form of boiling apparatus is the iron kettle. One of these may be swung from a chain or pole, or several may be arranged in a row as a battery, generally called a "Jamaica train" (fig. 12). Apparatus of this kind is seldom used, as the boiling process is laborious and the sirup thus obtained is very dark, with a poor flavor. The fresh juice is placed in the kettle next to the

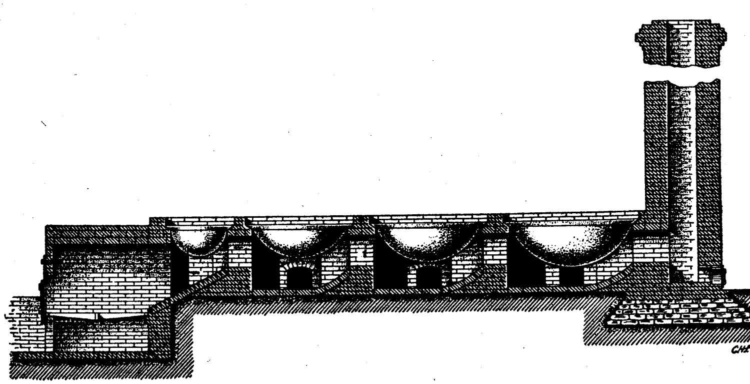

FIG. 12.—Jamaica train of kettles.

chimney and as it is heated it is ladled into the next one. The finished sirup is taken from the kettle immediately back of or over the fire box. When a single kettle is used, a fire is built around the outside of it, the raw juice is poured in, and the kettle is swung in to the fire. The greatest care must be used not to allow the flame to get above the level of the juice in the kettle; otherwise, it will burn and have a scorched taste. Another precaution necessary when making sirup in this kind of apparatus is to concentrate a single charge. Adding fresh juice to the boiling sirup always gives a dark-colored sirup, with a strong burnt flavor. After a charge has been concentrated, the kettle should be swung from the fire and the sediment washed out before it has had time to burn. If the kettle can not be removed from the fire, after two or three charges, remove the fire and clean the kettle.

No matter what type of evaporator is used, scum collecting on the surface of the boiling liquid must be removed as it forms. This is easily done with a skimmer. A metal sirup skimmer resembles an ordinary dustpan, with the bottom perforated. It may have a short handle (fig. 13), or a long wooden pole may be attached to it. Another form of skimmer often used is a pole with a narrow piece of metal fastened to it toward the end. By means of this the scum can be raked to the near edge of the pan and then lifted off by the regular skimmer.

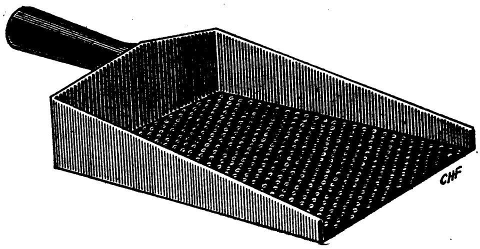

Fig. 13.—Sirup skimmer.

PANS AND PATENT EVAPORATORS.

Instead of kettles, shallow pans (not over 4 to 6 inches deep), made of galvanized iron, heavy tin, or sheet iron, are used by many makers. The use of sheet iron, however, is inadvisable as it tends to make the sirup dark. A single pan covers the whole space occupied by the kettles or two or three pans may be used, one back of the other. These may or may not be connected so that the juice can flow from one to another. Figure 14 shows a single pan with strips to guide the juice over a zigzag course during boiling. The juice comes in at the fire end and the finished sirup runs out at the chimney end. In some cases these pans are lifted from the fire for cleaning at the end of the day.

Many improvements have been made in the evaporation apparatus. Patent evaporators have many points of superiority to recommend them. The bottoms are usually corrugated to give a larger heating surface, the various compartments are connected, and an automatic supply valve is placed so that the depth of the liquid in the evaporator can be regulated. Their construction is such as to produce a quick concentration with less danger of burning or scorching the sirup.

Some makers prefer a homemade pan constructed of $1\frac{1}{2}$-inch boards, with a sheet-iron bottom carefully luted to the sides. This

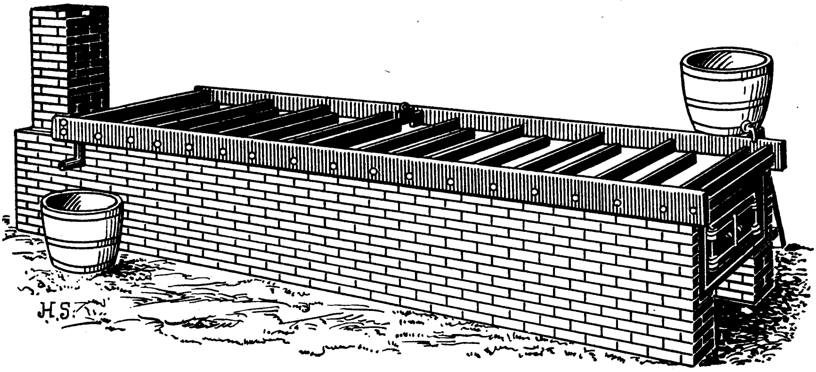

FIG. 14.—Pan evaporator.

form of pan can not be recommended under usual conditions for making a good grade of sirup. After being used once the wood becomes soaked with the juice, and if allowed to stand empty this juice sours and taints the next boiling. In the long run, they are more expensive than metal pans, as the wood soon warps, the joints become loose, and sirup is lost.

Figure 15 shows a portable evaporator which can be easily transported from one place to another and also tilted to allow a flow of juice and sirup. It is used extensively in some parts of the country.

When using these evaporators a thin layer of juice should be boiled to obtain the best grades of sirup. Not more than a $1\frac{1}{2}$ to 2 inch layer of juice should be in the pans or evaporator at any time, and with care even a thinner layer might be successfully carried. A thin layer evaporates quickly, as a consequence of which less color is developed when concentrating to a sirup. Also when boiling a thin layer the impurities reach the surface more easily, and by constant skimming a clear finished product is obtained. Deep boiling in such an apparatus produces the same effect as that obtained in iron kettles, namely, a dark, bad-tasting sirup. If an ordinary gutter is placed along each side of the pans, the scum can be raked off into this and then caught at the end in a bucket or tub. These skimmings make good food for hogs unless much lime has been added in clarification.

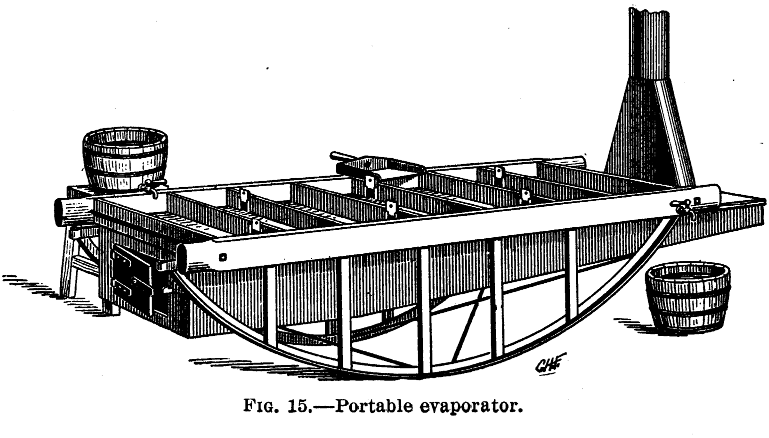

FIG. 15.—Portable evaporator.

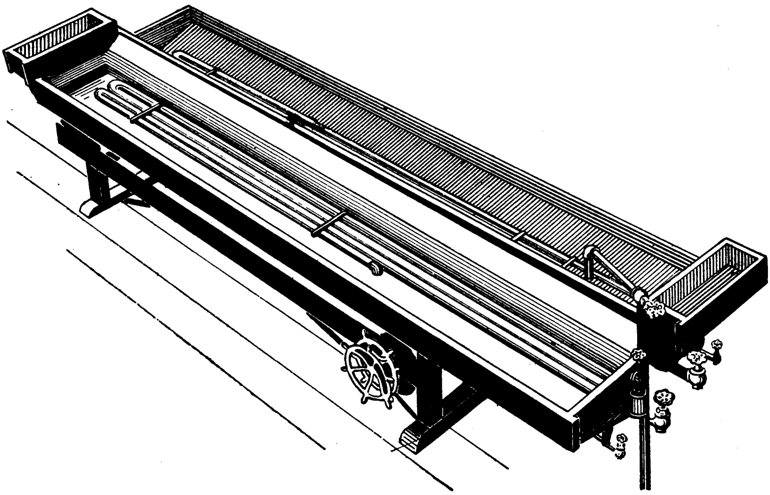

FIG. 16.—Steam evaporator.

In starting a patent evaporator always have water in all the parts and boil this until the raw juice enters. Never heat kettles or pans without water unless it is desired to burn the scale loose. Even this can generally be done in other ways, namely, by boiling water in the pans, either alone or with some acid, as muriatic acid. The acid, however, must be used with the greatest care, as it dissolves the metal of the evaporator. Scraping with an iron removes the scale, but it often spoils the evaporator, causing a leak at the place scraped.

STEAM EVAPORATORS.

Heating in steam evaporators is accomplished by means of steam coils. The most common form of such evaporators is a heavy wooden box lined with some metal, as galvanized iron, tin, or copper, and containing a coil of galvanized-iron or copper pipe. The coil is removable so that it can be cleaned. Figures 16 and 17 show two types of steam evaporators. In one type (fig. 16) one pan is used for heating and clarifying the juice and the other is used for evaporating it to sirup. When working on a large scale copper tanks with cop-

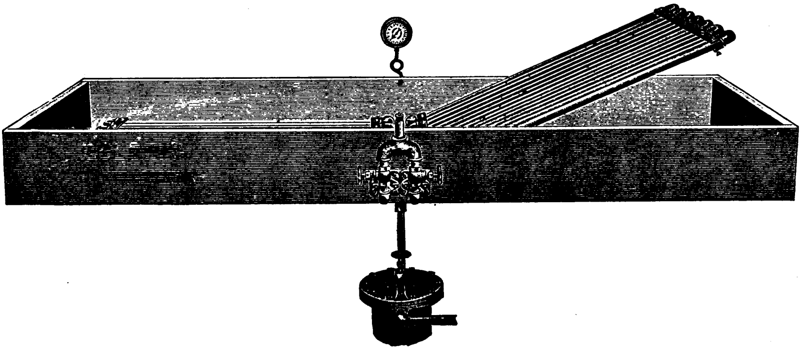

FIG. 17.—Steam evaporator.

per coils are used. The method of operation with steam heating is the same as with the fire evaporators, and there is much less danger of burning and darkening the sirup. The level of sirup should be not over half an inch to an inch above the coils.

DETERMINING THE FINISHING POINT.

Upon cooling, the finished sirup should have a moisture content of not over 30 per cent, or a solid content of not less than 70 per cent. One gallon of such sirup would weigh not less than 11¼ pounds. Commercial practice recognizes this as the minimum density for sorgo sirup. As the sirup comes from the evaporator it is rather difficult to fill and weigh a gallon measure, and such a weight will be correct only when the sirup is cooled to about 60° F. before being measured. Some makers determine the finishing point by pouring the sirup from a spoon and watching the last drops fall, but there are two methods which are superior and yet easy to perform. The first is noting the temperature at which the sirup is boiling and the other is to measure the density by means of a Baumé hydrometer.

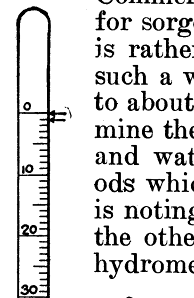

FIG. 18.—Hydrometer, outside and in the liquid.

By thermometer.—As a liquid thickens, the boiling point is raised. Water at ordinary pressure or at sea level boils at 212° F., while a sugar solution with 70 per cent of solids boils at 223.7° F. A thermometer placed in the boiling sirup shows roughly the density of the product. In testing a sirup for its density in this manner it is well to determine the accuracy of the thermometer by placing it in boiling water and noting the boiling point. Then finish the sirup at a point 12° to 13° higher than the boiling point of water. Altitude affects the boiling points of liquids. For every 500 feet above sea level, roughly speaking, the boiling point is lowered 1° F., so that water at a point 2,000 feet above sea level would boil at 208° F. and a finished sirup at 220° F. In taking the temperature, the bulb of the thermometer must not be allowed to touch the bottom or sides of the evaporator and must not be exposed above the surface of the liquid; otherwise, the reading will not represent the true temperature.

By hydrometer.—A hydrometer, or spindle, is an instrument for showing the density of a liquid. Hydrometers are graduated to various scales and for various purposes. The one generally used for rough sugar work is the Baumé. The standard of graduation is an arbitrary one, and varies somewhat with different makes. The usual Baumé hydrometer shows a graduation of zero to 50, divided into degrees (fig. 18). Being of glass, the instrument is rather fragile. The density is measured by floating the hydrometer freely in the liquid, which is generally held in a tall cylinder. The point on the scale where the instrument comes to rest is considered the density. With a raw juice, this varies from 4° to 10°, while for a finished sirup it should be 38° and over.

The temperature of standardization is 60° F., so for correct readings the sirup under examination should be cooled to that temperature. Sirup that gives a reading of from 35° to 36° when at boiling temperature usually gives a reading of from 39° to 41° when it has been cooled to 60° F. The accuracy of these glass hydrometers is very much affected by using them in hot liquids; hence it is not good practice to use an accurate instrument in the hot sirup. Table 2 shows the solid content and the water content for different degrees Baumé. These figures are only approximate.

TABLE 2.—*Dry substance and water corresponding to each degree Baumé.*

Degrees Baumé.[1]	Dry substance.	Water.	Degrees Baumé.[1]	Dry substance.	Water.	Degrees Baumé.[1]	Dry substance.	Water.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*
1	1.7	98.3	18	32.1	67.9	35	63.9	36.1
2	3.5	96.5	19	33.9	66.1	36	65.8	34.2
3	5.3	94.7	20	35.7	64.3	37	67.8	32.2
4	7.0	93.0	21	37.5	62.5	38	69.7	30.3
5	8.8	91.2	22	39.4	60.6	39	71.7	28.3
6	10.6	89.4	23	41.2	58.8	40	73.7	26.3
7	12.3	87.7	24	43.1	56.9	41	75.7	24.3
8	14.1	85.9	25	44.9	55.1	42	77.7	22.3
9	16.0	84.0	26	46.8	53.2	43	79.7	20.3
10	17.7	82.3	27	48.6	51.4	44	81.8	18.2
11	19.5	80.5	28	50.5	49.5	45	83.8	16.2
12	21.3	78.7	29	52.4	47.6	46	85.9	14.1
13	23.0	77.0	30	54.3	45.7	47	88.0	12.0
14	24.8	75.2	31	56.2	43.8	48	90.1	9.9
15	26.6	73.4	32	58.1	41.9	49	92.2	7.8
16	28.4	71.6	33	60.0	40.0	50	94.4	5.6
17	30.3	69.7	34	61.9	38.1			

[1] Taken at 60° F.

It is not to be understood that a degree Baumé corresponds to 1.7 per cent of sugar, for the hydrometer measures other dissolved solids also. When determining the density of the raw juice, a reading should not be made for about 20 minutes, or until all the air in the juice has escaped.

TREATMENT OF FINISHED SIRUP.

When the sirup has reached the proper density it should be quickly removed from the fire and cooled. Sirup that is cooled rapidly, for instance, by being run through a coil of pipe immersed in cold water, or permitted to cool in a large, shallow metal tank, usually has a lighter color than sirup that is run into a barrel and allowed to cool slowly. Sirup should be perfectly clear when proper care has been used in handling the juice and attention given to skimming during evaporation. In many cases, however, the appearance of the product is spoiled by the presence of suspended material that makes it cloudy. The best method for the removal of this cloudiness is to filter the sirup through felt, flannel, or some other type of gravity filter, such as a sand filter. This, however, is, at best, tedious, as the sirup, even when hot, filters very slowly. The semisirup, which filters somewhat more readily, may be filtered and the filtrate evaporated to the proper density. Both sirup and semisirup should be filtered hot.

A sand filter may be made by placing a layer, from 6 to 8 inches thick, of coarse, sharp sand, on a very fine mesh screen, in a tub or

box, the bottom of which is provided with many small holes for the escape of the filtered sirup. The sand should first be carefully washed.

No matter what type is used, the filter should be washed frequently and thoroughly with boiling water or with steam. When operating upon a large scale, a little infusorial earth may be added and the sirup filtered through pressure filters. These filters, however, are not suitable for small-scale producers.

If the sirup is not too heavy, standing causes the sediment to collect at the bottom and the clear sirup can be drawn off. For this purpose, tall milk cans, with one or two faucets placed 2 and 4 inches from the bottom, may be used (fig. 19). The sirup coming from the cooler can be placed in this and allowed to settle. A very heavy sirup, however, or one that is particularly gummy, may stand for as long as a week without much settling. If the cleansing is carefully done during the process of manufacture the finished sirup will not need further treatment.

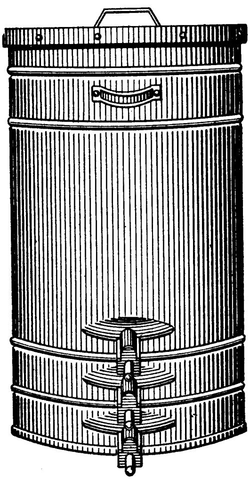

FIG. 19.—Settling can.

CANNING SIRUP.

Sirup may be placed in tin cans or in wooden or metal kegs or barrels. Whatever type is used, containers should be carefully washed with boiling water, and if possible thoroughly steamed. Fermentation may be prevented by cleaning the containers properly and handling the sirup carefully. Sirup which has been thoroughly sterilized by boiling does not ferment if packed while hot in clean containers which have been sterilized with scalding water or steam and sealed immediately. The containers must be perfectly air tight; otherwise, fermentation and molding may occur.

Sorgo sirup may be graded as to color and flavor by fixing standards and grading the output. This is most important in supplying a local market, and it might be of value to the makers of sorgo sirup in a certain locality to unite and sell their product under such conditions. As a rule, buyers of such a commodity desire two purchases of the same material to have the same color and flavor. They are not informed as to why manufacturing conditions affect these and why all sorgo sirup is not of the same appearance and taste. By having an association of farmers and a system of grading, different products can be classified. As maple-sirup makers have found this plan of value, it might be profitably applied to the sorgo-sirup industry.

PREVENTION OF CRYSTALLIZATION.

Crystallization results from making a supersaturated solution of a substance in a liquid. In the case of sirups the sucrose (ordinary sugar) becomes concentrated to a point at which it is no longer soluble in the water present; hence it crystallizes out. This is the fundamental principle of recovering or manufacturing sugar. In

these processes every care is taken to prevent the destruction of sucrose during manufacture, so that a high yield of sugar will be obtained. In the manufacture of sirup it is desirable to avoid crystallization, or "sugaring out." The following precautions will lessen the danger from this.

On being heated in the presence of an acid or in water for a long time and at a high temperature, sucrose is broken down into what is technically called "invert sugar." This has a sweet taste and a food value almost identical with that of sucrose. The presence of invert sugar in sirup retards, and if present in sufficient quantity prevents, the crystallization of sucrose. When raw sorgo juice is boiled, the natural acidity causes some of the sucrose to be changed into invert sugar and lessens crystallization of the finished sirup. For this reason, juice that has been clarified should be left decidedly acid. In most cases this natural acidity is sufficient to prevent crystallization, but when the sorgo is very ripe and has a high sucrose content the sirup may crystallize. Some makers secure the desired inversion by allowing the sorgo stalks to remain in the field for 24 hours or longer after being cut. This is done extensively in sorgo-sirup manufacture, and many producers state that the flavor of the sirup is not impaired by this treatment unless the stalks have been cut for so long that fermentation has begun. Sorgo juice as expressed from the stalks contains a little starch and gummy material. If these are not removed during settling and clarification, they assist in preventing crystallization. It is not the usual policy, however, to allow them to remain in the juice for this purpose (although they are sometimes present, owing to poor settling and skimming), as they influence the flavor of the sirup. The danger of crystallization in sorgo sirup is much less than in cane or maple sirup. Long standing, however, in a cool place may cause crystals of sugar to form.

ECONOMIC CONSIDERATIONS.

LOCATION AND ARRANGEMENT OF A SIRUP PLANT.

The small maker should consider carefully the location and arrangement before putting up a plant. It is impossible to enter into a thorough discussion of this subject or to lay down hard and fast rules. The boiling house, etc., however, should be easily accessible for bringing in the stalks and fuel and for storing and taking care of the finished product. In a small plant it is not necessary to cover all the equipment.

The mill should be placed on the highest level, the raw juice should be caught at a lower point, and the evaporator should be placed lower. In this way gravity is made to play an important part. This same idea can be carried out with power mills. In manufacturing on a larger scale, the mill is best placed on the ground, the raw juice is pumped into storage tanks placed higher up, from which it runs down through the clarifiers to the evaporators on the ground floor. The evaporator, however, should be given sufficient elevation to insure a convenient handling of the finished sirup.

Under all conditions the boiling house should be covered and provided with a good ventilator in the top to dissipate the steam, and

should be inclosed on all sides to prevent the blowing of cold drafts of air on the pan, thus retarding evaporation. It is advantageous to have sections of the siding hinged at the top in such a manner as to allow them to be opened outward (fig. 20). These sections may then be regulated to facilitate the removal of steam without permitting the entrance of an unduly large amount of cold air. If possible the floor of the boiling house should be paved with brick, wood, or cement, and sloped to furnish drainage. If a fire evaporator is used it is well to have a partition at the fire door, so that when stirring the fire or adding fuel no ashes will get into the sirup.

In a word, the arrangement should be such that the evaporation can be done quickly and under cleanly conditions. Many makers use their maple camps for making sorgo sirup also. The same camp and arrangements will serve admirably for the two, providing the location is convenient.

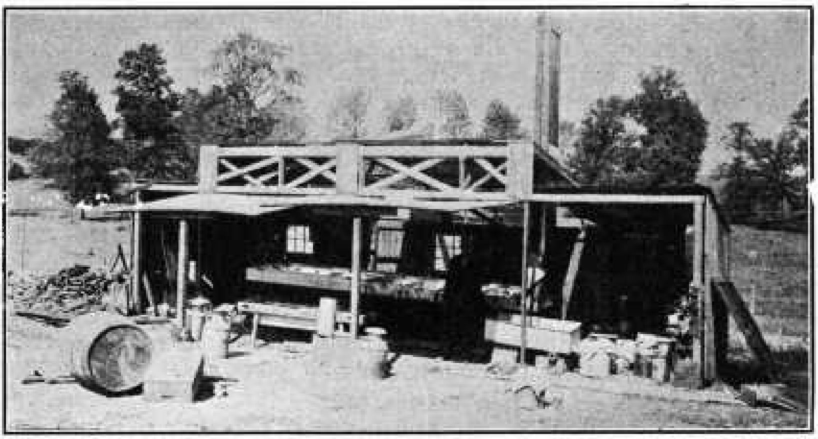

Fig. 20.—Evaporation house.

A power mill should be covered; in fact, it could well be placed in a house similar to the boiling sheds shown in Figure 20, with sides capable of being raised. The evaporation house might be made large enough to hold the engine and the mill.

FUEL.

The fuel for the evaporation and other processes is a very important item. That one should be selected which is the cheapest for the work to be done, whether it be wood, coal, or oil. Several makers use a crude-oil burner under their evaporators. This, in connection with a jet of steam, gives a good fire for evaporation and one capable of adjustment. Many trials have been made in using the bagasse (crushed stalks) as it comes from the mills as a fuel, but a special fire box is necessary for this purpose.

An arrangement for burning bagasse on a small scale under pans or evaporators (fig. 21) consists of a sheet-iron funnel tapering toward the end nearest the furnace, so as to compress this light fuel slightly

as it is pushed through into the furnace, and having a sheet-iron door hinged to the upper surface. This is a safer and better method of firing than to put the bagasse directly on the fire. A fork full of the fuel pushes the door inward, and the door closes itself when the fork is withdrawn.

Another form consists of a small oil burner in the furnace, the bagasse being fed to the fire by hand. There may be some danger, however, in this kind of firing.

The greatest trouble with bagasse is its high moisture content, as the usual mill does not press the stalks dry. By spreading the material out in the sun, however, a good fuel may sometimes be obtained in favorable seasons. In the sugar-cane industry of Cuba the bagasse furnishes in many cases from 90 to 100 per cent of the fuel for operating the whole plant. The bagasse from large mills is drier than that obtained by small-scale sorgo sirup makers, and burning bagasse on a small scale is not usually recommended.

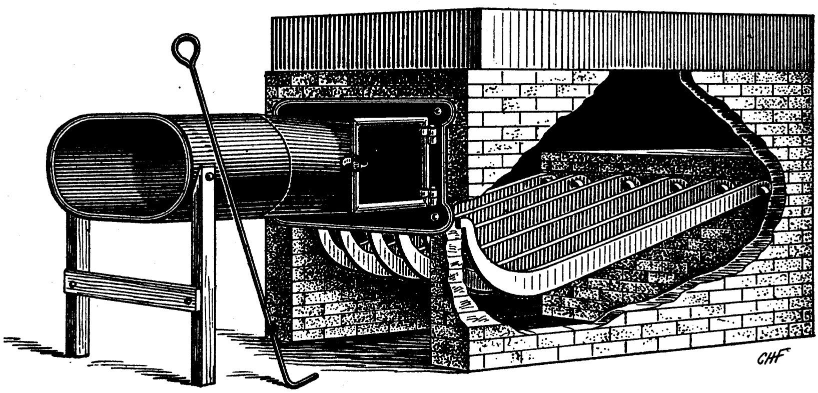

FIG. 21.—A bagasse burner.

MAKING SIRUP ON SHARES.

Farmers may often grow sorgo, without caring to manufacture it into sirup. Upon what basis should the sirup be made? A central factory seldom raises all its own sorgo—it buys a part of its requirements from the farmers. In this case the agreement is generally drawn up for the cut material, free of trash, and either stripped or not stripped of leaves, at a given price per ton of raw material. On a small scale this is seldom done, one of two general methods being followed in such cases. The maker produces the sirup either at a stated price per gallon for the farmer or on shares, that is, giving the farmer a certain number of gallons of sirup (5 to 15) for each ton of raw material.

When several lots of sorgo are to be worked up, the following method may be used to do away with the necessity for boiling the juice from each lot separately. The material is ground separately and the juice from each lot is collected in tanks where it can be measured. From the number of gallons of juice and its Baumé

reading (p. 18), the number of gallons of sirup that will be made may be calculated with a fair degree of accuracy.

The settling tanks are convenient for measuring the raw juice. If the tank is square, take the inside dimensions, length and width, in inches, multiply these together and divide the result by 231 (the number of cubic inches in a gallon) to obtain the gallons of juice in the tank for each inch of depth. By inserting a stick or rule in the tank the number of inches of juice is obtained, and this figure multiplied by the gallons per inch of depth, gives the number of gallons of raw juice.

If the measuring tank is round, multiply the diameter, in inches, by the diameter, in inches (identical figures). Multiply this result by 0.7854 and divide the result by 231. The figure thus obtained shows the number of gallons of juice in the tank for each inch of depth.

The other figure necessary for the calculation is the density of the juice as determined by means of a Baumé hydrometer. This instrument can be placed in the tank, provided the juice is deep enough to allow it to float freely. From these two figures the yield can be obtained. In one typical case[4] 10 gallons of juice with a reading of 6° Baumé made 1 gallon of finished sirup. From this the following sliding scale was calculated.

Juice, degrees Baumé.	Gallons of juice per gallon of sirup.
6	10
6½	9
7	8½
7½	8
8	7½
8½	7
9	6½
10	6
11	5½
12	5

The number of gallons of juice, multiplied by the Baumé reading, gives approximately 60 in every case. Each maker can and should prepare for himself such a table, as his method of manufacture may not be like the one used here. To do this it is necessary to obtain the Baumé reading of several tanks of juice, then concentrate the juice to a sirup in the usual way, and measure the finished sirup. Multiplying the Baumé reading of the juice by the number of gallons of raw juice and dividing by the number of gallons of finished sirup made gives the figure on which to base the table (60 in the present case). With this beginning, a table can be prepared for different Baumé readings on the raw juice. In this way as soon as a separate lot is ground the juice can be measured, the density determined, and the number of gallons of sirup due the cane grower learned without interfering with the work of the evaporator.

EFFECT OF STRIPPING UPON SUGAR CONTENT OF JUICE.

The effect of stripping sorgo is shown in Table 3. These figures were obtained by dividing a quantity of cut stalks into two portions, one of which was carefully stripped, milling the two samples

[4] U. S. Dept. Agr., Farmers' Bulletin 135, p. 39.

in succession, and obtaining a representative sample of juice from each for analysis.

TABLE 3.—*Composition of sorgo, stripped and unstripped, arranged according to varieties.*

Variety and condition.	Density.	Sucrose.	Invert sugar.	Total sugar.
	Degrees Baumé.	*Per cent.*	*Per cent.*	*Per cent.*
Sumac:				
Unstripped	7.4	4.14	7.57	11.71
Stripped	7.6	4.74	7.50	12.24
McLean:				
Unstripped	9.2	5.28	11.39	16.67
Stripped	11.1	13.76	6.66	20.42
Mixed:				
Unstripped	8.65	7.39	9.29	16.68
Stripped	8.4	9.01	6.82	15.83
Honey:				
Unstripped	6.4	2.83	7.92	10.75
Stripped	6.4	3.20	7.23	10.43
Mixed:				
Unstripped	7.9	4.57	9.02	13.59
Stripped	7.9	5.96	7.43	13.39
McLean:				
Unstripped	9.3	3.19	11.95	15.14
Stripped	10.2	12.14	4.23	16.37
Mixed:				
Unstripped	8.1	4.83	8.58	13.41
Stripped	8.0	5.73	7.63	13.36
Honey:				
Unstripped	6.2	0.22	10.50	10.72
Stripped	6.3	2.32	8.42	10.74
Average:				
Unstripped	7.89	4.06	9.53	13.59
Stripped	8.24	7.11	6.99	14.10
Average, excluding the McLean samples:				
Unstripped	7.44	4.00	8.81	12.81
Stripped	7.43	5.16	7.51	12.67

With each variety the percentage of invert sugar is greater in the juice from the unstripped than in that from the stripped stalks, while the percentage of sucrose is greater when the stalks are stripped. With the exception of the McLean variety, which has large, heavy, green leaves, the difference in the percentage of total sugars is very slight.

It seems, then, that there is no material difference in the quantity of sirup that can be produced from a given quantity of juice from either stripped or unstripped sorgo, unless the leaves are very abundant and full of juice. From the statements on page 21, it might seem that allowing the leaves to remain tends to prevent crystallization of the sirup, owing to the increased quantity of invert sugar in the juice. As stated on page 6, however, allowing the leaves to remain tends to make clarification more difficult and may give a bad flavor to the juice and resulting sirup. Also, when the leaves become dry juice may be lost through absorption by the dry leaves during milling. It is believed that where the sorgo is cut with the leaves still attached and allowed to remain in the field for about 24 hours, a portion of the juice of the leaves returns to the stalk as the leaves wither, with a corresponding increase in the quantity of invert sugar in the juice finally obtained. For the reasons already given, however, the leaves should be removed before milling.

BY-PRODUCTS.

Bagasse.—The crushed sorgo as it comes from the mill is known as bagasse, and its use as a fuel is discussed on page 22. It is also of value as a fertilizer and when spread over fields and plowed under restores some of the fertilizing ingredients taken from the soil by the plant. In some sections it is customary to give cattle access to the bagasse which has been spread over the fields, care being taken not to let them eat too much of it at first. Bagasse mixed with varying proportions of cottonseed meal, molasses, etc., has also been used as a dry dairy feed. Although sugar-cane bagasse has been employed in making paper board, the use of bagasse for this purpose has not yet been largely developed.

Leaves.—In stripping, from 5 to 15 per cent of the weight of the crop is removed; in other words, the leaves when green weigh on an average about 10 per cent of the topped sorgo. If they are frost bitten or dry, or both, they may not be over 4 per cent of the weight. Some makers on buying sorgo consider a long ton of unstripped material equivalent to a ton of stripped material—that is, 2,240 pounds are equivalent to 2,000 pounds, which would make the leaves and dirt amount to 10.7 per cent. As some varieties bear more leaves than others, only average figures can be given. The leaves make a good cattle food, or by allowing them to remain in the fields and plowing under, they are of value as a fertilizer. The leaves have also been used in making silage.

Seed heads.—The quantity of seed per acre varies with the variety of sorgo and the stand. Estimates ranging from 5 to 30 bushels to the acre are given, an average figure for the usual varieties being from 10 to 15 bushels. They have a large feeding value, claimed by some to be equal to corn, although most authorities give them a place much below corn. On account of the shape and hardness of the seed, better feeding results are obtained by first boiling or grinding them. Because of the difficulty of removing the hulls and the astringency of the seed coating, the grain is less relished by animals than is that of the nonsaccharine varieties of sorghum.

COMPOSITION OF SORGO.

The results of analyses of sorgo grown in various places during 1910 are given in Table 4.

The samples of Collier and Colman show very high percentages of sucrose with low invert sugar contents. It is doubtful whether the average run of sorgo of these varieties gives such high figures, but they serve to show the results that may be expected when it is produced under favorable conditions.

PRODUCTION OF SORGO SIRUP.

The relative production of sorgo sirup in the various States is indicated by the figures in Table 5, which were obtained from the United States Census reports.

These figures are only approximately correct, as much of the sorgo sirup is made on a very small scale and is probably not reported.

TABLE 4.—*Composition of sorgo, arranged according to varieties.*

[Results are analyses of expressed juice]

Variety and locality.	Density.	Sucrose.	Invert sugar.	Total sugar.
	Degrees Baumé.	*Per cent.*	*Per cent.*	*Per cent.*
Sumac:				
Biloxi, Miss	8.1	4.07	7.37	11.44
Do	10.1	10.93	3.21	14.14
Dalhart, Tex	10.6	11.34	3.49	14.83
Do	8.6	2.88	10.90	13.78
Brownsville, Tex	9.0	8.52	4.74	13.26
Do	8.0	4.26	6.70	10.96
Planters:				
Biloxi, Miss	9.7	10.59	1.91	12.50
Arlington, Va	9.7	2.98	10.70	13.68
Do	11.3	4.15	11.69	15.84
Compton, Calif	9.7	9.27	3.28	12.55
Monette, S. C	11.6	14.47	2.84	17.31
Do	12.2	15.38	1.74	17.12
Brownsville, Tex	7.3	5.58	3.86	9.44
Do	7.9	8.22	2.05	10.27
Dalhart, Tex	8.4	4.15	5.78	9.93
Do	8.6	3.17	6.54	9.71
Red amber:				
Biloxi, Miss	9.3	9.57	2.72	12.29
Arlington, Va	9.2	0.75	12.57	13.32
Do	10.0	3.02	11.65	14.67
Monette, S. C	10.4	6.41	8.70	15.11
Compton, Calif	11.9	1.43	14.46	15.89
Dalhart, Tex	6.3	1.88	6.32	8.20
Brownsville, Tex	8.3	4.64	6.87	11.51
Do	7.4	1.81	7.64	9.45
Minnesota amber:				
Biloxi, Miss	10.7	12.89	1.72	14.61
Arlington, Va	10.0	3.54	11.15	14.69
Do	10.5	4.26	11.40	15.66
Compton, Calif	7.5	5.77	2.95	8.72
Monette, S. C	10.7	13.00	2.03	15.03
Dalhart, Tex	7.4	4.98	4.54	9.52
Do	8.5	4.82	6.78	11.60
Brownsville, Tex	7.2	5.01	4.18	9.19
Do	8.0	4.37	6.98	11.35
Orange:				
Biloxi, Miss	10.3	12.32	1.88	14.20
Arlington, Va	8.1	2.86	7.35	10.21
Do	10.5	1.66	14.62	16.28
Compton, Calif	9.2	7.99	3.38	11.37
Monette, S. C	....	14.30	1.75	16.05
Do	12.7	15.53	2.14	17.67
Dalhart, Tex	6.2	1.70	5.72	7.42
Brownsville, Tex	6.8	2.64	5.91	8.55
Do	9.6	8.14	5.35	13.49
Honey:				
Biloxi, Miss	8.6	8.22	4.44	12.66
Arlington, Va	11.0	3.58	13.57	17.15
Do	11.2	11.46	4.48	15.94
Compton, Calif	11.6	12.59	1.50	14.09
Dalhart, Tex	9.7	1.73	11.97	13.70
Brownsville, Tex	8.3	5.66	5.78	11.44
Do	8.7	8.44	3.42	11.86
Gooseneck:				
Biloxi, Miss	8.9	8.67	4.42	13.09
Arlington, Va	8.7	3.84	8.80	12.64
Compton, Calif	8.5	7.39	2.91	10.30
Dalhart, Tex	10.5	10.48	4.63	15.11
Colman:				
Compton, Calif	11.9	13.79	1.12	14.91
Monette, S. C	....	15.30	1.28	16.58
Do	11.2	14.25	1.93	16.18
Collier:				
Compton, Calif	10.9	12.14	2.12	14.26
Monette, S. C	13.7	18.39	0.61	19.00
Do	14.0	18.24	0.92	19.16
Average	9.6	7.62	5.62	13.24

TABLE 5.—*Production of sorgo sirup in the United States (1859–1919).*

State.	1919	1909	1899	1889	1879	1869	1859
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
Alabama	2,429,302	809,361	1,168,868	1,242,689	1,163,451	267,269	55,653
Kentucky	2,044,098	2,733,683	1,277,206	2,094,962	2,962,965	1,740,453	356,705
Tennessee	1,917,293	2,076,339	2,047,655	2,542,533	3,776,212	1,254,701	706,663
Georgia	1,820,165	740,450	767,024	1,342,803	981,152	374,027	103,490
Mississippi	1,795,368	622,356	1,162,269	972,216	1,062,140	67,509	1,427
Texas	1,689,205	448,185	877,232	1,749,910	432,059	174,509	112,412
Arkansas	1,438,748	1,140,532	1,223,691	1,868,952	1,118,364	147,203	115,604
Missouri	1,414,222	1,788,391	1,990,987	2,721,240	4,129,595	1,730,171	796,111
North Carolina	1,397,980	1,099,346	1,419,570	1,268,946	964,662	621,855	263,475
South Carolina	900,206	262,452	478,190	559,216	281,242	183,585	51,041
Oklahoma	704,083	514,807	179,272	31,299	...	...	...
Indiana	681,190	965,086	579,061	751,808	1,741,853	2,026,212	881,049
Virginia	598,774	441,189	555,321	546,328	564,558	329,155	221,270
Iowa	587,712	250,205	521,212	1,386,605	2,064,020	1,218,636	1,211,512
Illinois	527,981	977,238	625,939	1,110,183	2,265,993	1,960,473	806,589
West Virginia	451,875	604,201	450,777	512,747	817,168	780,829	...
Ohio	290,059	354,131	341,523	547,630	1,229,852	2,023,427	779,076
Wisconsin	207,277	139,667	160,414	219,070	314,150	74,478	19,854
Kansas	(1)	260,680	735,787	1,484,937	1,429,476	449,409	87,656
Minnesota	(1)	145,934	157,605	340,792	543,369	38,735	14,178
Louisiana	(1)	47,029	48,727	107,763	33,777	180	...
Florida	(1)	22,177	...	10,461	10,199	...	...
Utah	(1)	21,847	28,017	24,293	58,221	67,446	25,475
Michigan	(1)	21,350	24,059	45,524	102,500	94,686	86,953
Nebraska	(1)	14,644	92,413	634,146	246,047	77,598	23,497
New Mexico	(1)	5,289	2,812	3,510	251	1,765	1,950
Delaware	(1)	4,517	8,952	3,371	25,136	65,908	1,613
California	(1)	4,330	8,671	1,670	2,459	333	552
Arizona	(1)	3,967	9,031	4,808	5,771	...	...
Pennsylvania	(1)	2,585	6,514	33,708	69,767	213,373	22,749
Colorado	(1)	2,547	2,661	19,964	3,227	...	...
South Dakota	(1)	2,030	9,859	29,372	[2] 17,012	[2] 1,230	[2] 20
Maryland	(1)	1,782	4,058	4,732	19,837	28,563	907
Oregon	(1)	1,374	2,473	2,706	2,283	...	315
Nevada	(1)	1,266	1,465	930	350	3,651	...
Washington	(1)	634	438	1,125	1,472	612	...
Idaho	(1)	407	1,393	3,093	36	...	...
Montana	(1)	223	100	...	...	...	...
North Dakota	(1)	102	114	10	(3)	(3)	(3)
New Jersey	(1)	35	450	281	1,261	17,424	396
New York	(1)	14	973	8,305	1,134	7,832	516
Wyoming	(1)	...	...	120	...	...	...
Connecticut	(1)	...	...	214	1,163	6,832	395
Maine	(1)	...	...	152	...	...	...
New Hampshire	(1)	...	...	50	...	...	...
Vermont	(1)	...	...	45	...	...	...
Massachusetts	(1)	...	...	...	18	...	...
Rhode Island	(1)	...	...	...	...	20	20
Total	21,523,025	16,532,382	16,972,783	24,235,219	28,444,202	16,050,089	6,749,123

[1] Reported under "all other States" as 627,487 gallons.
[2] Dakota Territory.
[3] Included in Dakota Territory; reported under South Dakota.

Statistics obtained by the United States Department of Agriculture show the following total production of sorgo sirup in the United States from 1919 to 1922:

Year.	Gallons.
1919	39,413,000
1920	49,505,000
1921	45,566,000
1922	36,532,000

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December 17, 1923.

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